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Framework for Assessing Virtualization Maturity of Universities

Maria Mach-Król

Department of Business Informatics, University of Economics in Katowice, Poland
https://orcid.org/0000-0002-7234-7340

Tomasz Gładysz

Wroclaw University of Economics and Business, Poland
https://orcid.org/0000-0002-2845-3947

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Abstract

Purpose: The main purpose of this paper is to discuss universities' virtualization activities and to propose a framework for assessing the maturity of these actions at any university.
Design/methodology/approach: The maturity model has been developed according to the Design Science Research in Information Systems (DSRIS) methodology as outlined by Vaishnavi, Kuechler and Petter (2019).
Findings: The main finding in the paper is a new framework called Virtual Index of Maturity (VIM) that can help to measure the current state of universities' virtualization activities and to plan their future development. The proposed framework includes all areas of their activity: teaching, research and administration and allows for assessing the virtualization maturity of each of them, considering their specificity. Consequently, the overall information on universities' maturity in the context of virtualization activities is obtained. Such information can be used by university authorities to plan subsequent steps of development.
Research limitations/implications: Once published and applied, the proposed framework of the Virtual Maturity Index (VIM) should be evaluated as part of further research, with any necessary corrections as deemed necessary. This should lead to the development of best practice for university managers, researchers and other stakeholders involved in virtualization issues.
Originality/value: Our paper provides important contributions to both theory and practice in the area of universities' virtualization operations. The Virtual Maturity Index (VIM) is a proprietary, original solution.

Keywords: virtualization, maturity index, university.

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Correspondence address: Department of Business Informatics, University of Economics in Katowice, 1 Maja 50, 40-287 Katowice, Poland; e-mails: Maria.Mach-Krol@ue.katowice.pl; Tomasz.Gladysz@ue.wroc.pl.

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Ramy oceny dojrzałości wirtualnej uczelni

Streszczenie

Cel: dyskusja na temat działań uczelni w zakresie wirtualizacji oraz zaproponowanie ram oceny dojrzałości tych działań.
Metodologia: podczas pracy nad modelem dojrzałości wykorzystano metodykę Design Science Research in Information Systems – DSRIS zaproponowaną w pracy Vaishnavi, Kuechler i Petter (2019).
Wyniki: zbudowanie Wirtualnego Indeksu Dojrzałości (VIM), który jest pomocny w pomiarze aktualnego stanu uczelni w zakresie wirtualizacji oraz w planowaniu ich przyszłego rozwoju. Zaproponowane rozwiązanie obejmuje wszystkie obszary działalności uczelni: dydaktykę, badania i administrację oraz pozwala ocenić dojrzałość wirtualną każdego z nich z uwzględnieniem jego specyfiki. W efekcie uzyskuje się ogólną informację o dojrzałości uczelni w kontekście działań wirtualizacyjnych, które mogą być wykorzystane przez władze uczelni do planowania kolejnych etapów rozwoju.
Ograniczenia/implikacje badawcze: zaproponowany model Wirtualnego Indeksu Dojrzałości (VIM) po fazie upublicznienia i stosowania powinien w ramach dalszych badań zostać poddany ewaluacji i powinny być naniesione ewentualne korekty. Stosowanie i ewaluacja powinny doprowadzić do opracowania najlepszych praktyk dla kierowników uczelni, badaczy i innych interesariuszy zajmujących się kwestiami wirtualizacji.
Oryginalność/wartość: artykuł wnosi ważny wkład zarówno w teorię, jak i w praktykę w obszarze operacji wirtualizacji uczelni. Wirtualny Indeks Dojrzałości (VIM) jest autorskim rozwiązaniem oryginalnym.

Słowa kluczowe: wirtualizacja, indeks dojrzałości, uniwersytet.

1. Introduction and Motivation

The higher education sector is facing numerous and serious challenges all over the world. These include both demographic trends, social changes and rapid technological changes affecting the way educational services are provided. There are also additional challenges that arise from the Bologna Process (Dziewanowska, 2016). Also, the requirements of the modern market – the more and more digital one – pose new global challenges to science. In the assessment of academic units, scientific achievements that have a global reach are considered. The reasons for this situation can be seen in the development of a network society, scientometry, bibliometry and the research market, scientific implementations, and publications (Sułkowski et al., 2018).

Technological solutions offered by the internet not only contributed to the depreciation of geographic access barriers. They also contributed to the evolution and development of various organizations, not only business but also educational ones. The name of this revolution is called virtualization. Businesses have transferred a lot of their activities to the cyberspace, treating this move as one of the means to survive on the competitive market. Virtualization not only allows for reaching a wider base of customers but also permits cooperating with various business partners.

The same phenomenon concerns universities. To be competitive on the educational market, universities do have to transfer at least part of their various activities to the internet, they need to facilitate cooperation

between students and researchers from all over the world. It is also obvious that the COVID-19 pandemic contributed a lot to the increased need for virtualization of universities. However, the degree to which various areas of a university's activity are virtualized is sometimes difficult to assess. Moreover, as any other process, also the virtualization process should be ordered and easy to follow. For these reasons, there was a need to create a tool that would help universities to assess the degree of their virtualization and indicate the steps that should be taken to move to the next level. Such a tool is proposed by us in this paper – the framework for assessing virtualization maturity of universities.

Our framework encompasses all the areas of activity at a university: teaching, research, and administrative ones. Every area is assessed separately, and our framework allows for combining these partial assessments to obtain the overall information on the university's route to success in virtualization.

The maturity model has been developed according to the Design Science Research in Information Systems (DSRIS) methodology as outlined by Vaishnavi, Kuechler and Petter (2019) (cf. Section 2).

The rest of this paper is organized as follows. Section 2 presents methodological considerations. In Section 3, we outline the theoretical background covering the issues of virtualization, e-learning, e-administration, and e-research at universities. Section 4 is devoted to related works. In Section 5, we introduce the general idea of maturity models. Section 6 contains the presentation of our framework. In Section 7, the summary of our findings, concluding remarks, and possible future research directions are presented.

2. Methodological Issues

The research aimed at building the virtualization maturity model of universities has been conducted according to the Design Science Research in Information Systems (DSRIS) by Vaishnavi, Kuechler and Petter (2019). The DSRIS constitutes a sound framework for carrying out design science-related research projects. It is well-grounded not only in the literature on design science in the field of information systems, but also in IS-related disciplines. Moreover, it is perceived as very flexible, which makes it particularly useful for building also theoretical artifacts in the IS-related domains.

The adopted research framework is composed of five process steps:

1. Awareness of the problem,
2. Suggestion,
3. Development,
4. Evaluation,
5. Conclusion.

Each of these steps produces a specific output. Step 1 results in the formulation of a proposal, step 2 ends with a tentative design, step 3 allows

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to design the artifact itself, in step 4 performance measures are applied to verify the artifact, finally step 5 gives the final results of research.

The first stage – awareness of the problem – encompassed literature research on virtualization and appropriate maturity models. This step allowed us to name a research gap which originates from the fact that the virtualization maturity of higher education institutions is not covered by research (cf. Sections 3 & 4). The need for a tool to measure universities' virtualization maturity and to help establish a path to virtualization has also been confirmed by interviews (not yet published) with the research and teaching staff and authorities of several universities in Poland.

The second stage – suggestion – consisted of a further analysis of literature and of discussions which led to the first idea of the VIM and of the virtualization maturity model for universities. This stage allowed for identification of the most important dimensions in universities' activity and of universities' virtualization indicators.

In the process of artifact development (stage 3), the VIM and the maturity model were further elaborated based on the outputs from stages 1 and 2, with the help of creative thinking and interpretive philosophy. The VIM and the maturity model have been described in detail (cf. Section 6). Stages 4 and 5 have not been completed yet, as the proposed framework needs further verification (cf. Section 7).

3. Background

3.1. The Notion of Virtualization

The concept of virtualization and virtual organization has been discussed in the literature for many years. However, it is not strictly defined. There are many definitions which differently emphasize the relevance of an object's properties for classification in the "virtual" group. Perechuda (1997) defines a virtual organization as a modern organizational model that optimizes the play on intangible resources (Perechuda, 1997). The idea of a virtual organization is expressed in the form of multifaceted and multifactor system transformations taking place in various economic entities. These transformations are aimed at eliminating inefficient supply channels, reducing extended routes of information stream flow, and transforming sluggish hierarchies into flexible organizational units with high autonomy and a high standard of activities in the field of operative management of widely understood production and work (Niedzielska, 1997). Kisielnicki (1998) claims that a virtual organization is based on the voluntary participation of members who enter various new types of relationships with each other in order to achieve greater benefits as compared to those gained from traditional cooperation. According to Olejczyk (2000), a virtual organization is a company that operates in computer networks (internet) or that, in

addition to functioning in the traditional market, also conducts activities (mainly sales and promotional activities) in the virtual market. Also, a virtual organization is a dynamic management tool based on computer networks and the possibilities of using information banks, such as the internet, among others, which is ideal for achieving competitive advantage in the global market (Grudzewski & Hejduk, 2002).

Some of these definitions (i.e., Perechuda, Niedzielska, Kisielnicki) focus on the structure, emphasize the loosening of ties and ability to modify quickly, define this state as cooperation of independent units with high (if not total) autonomy. Due to legal requirements, university structures must remain within certain clearly defined limits imposed by regulations (including, among others, the Law on Higher Education and any implementing regulations). Therefore, it is difficult to talk only about juxtaposed various configurations – in response to the demand – of forms of cooperation of completely independent and autonomous entities.

Virtual space is derived from selected components of other spaces. According to Warner and Witzel (2005), the virtual space is created by:
– imaginative space,
– technological space,
– cultural space.

Analyzing selected definitions in the context of university virtual maturity, it may be concluded that the approach best suited to this specific situation is the one focusing, in the initial stages, on the use of information technology and the internet and, in later, already more advanced stages, on the use of implemented technologies to concentrate on network activities. After elimination of elements suggesting the necessity of referring to business and sales, in compilation with Perechuda's definition, the definition derived from those given by Olejczyk and Grudzewski and Hejduk is best suited to work on the concept of university virtualization. In this paper, we propose our definition of university virtualization, clearly indicating two stages, as follows:

A virtual organization is created through the increasing use of information communication technologies in its activities, it is based on computer networks and the possibility of using internet information banks. By transferring a significant part of its activity to the internet, a virtual organization starts to operate in a networked way. Depending on the degree of virtualization, it can also conduct activities in the traditional (real) space apart from functioning in the internet (virtual) space.

Hence, virtualization of the university at an early stage is the transfer of activities to the internet space through the increasingly intensive exploitation of information communication technologies based on computer networks and the possibility of using electronic databases and internet information banks. Then, at a later stage, after the implementation of available technologies, a sufficiently large part of activities is transferred to the digital space. Activities are organized virtually, e.g., in the educational sphere of

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inter-faculty and inter-university studies, in the administrative sphere of common inter-university units such as a libraries, dormitories, and in the research sphere of participation in joint scientific projects or establishment of consortia.

In the proposed definition, being active in the online space is an indispensable component of a virtual organization at any level of virtualization, but reaching higher levels also requires virtual organization of all activities – technology alone is not sufficient. This definition does not close the possibility of conducting activities in real space and it allows for a gradation of virtuality depending on the mutual distribution of activities: the relatively larger part of the organization's activities takes place in the virtual space and the more activities are organized virtual, the more virtual the organization is. Adopting such an approach, it can be said that currently there are no organizations that are 100% virtual, also in the context of cooperation between universities or other research institutions, as due to legal and formal restrictions, they must have basic elements for activities in the traditional space (an example here is the headquarters – an address that cannot be just an internet address). Virtualization should be understood as a transition from a traditional organization to an increasingly virtual organization. This approach to defining virtualization, consequently, allows the presentation of our virtual university maturity model which will be discussed in detail in Section 6.

3.2. E-learning Issues

In connection with the rapid development of information and communication technologies, allowing for the expansion of the distance teaching process, i.e. in the virtual space (cyberspace), entities have appeared in the market of educational services that offer the opportunity to participate in classes without leaving home.

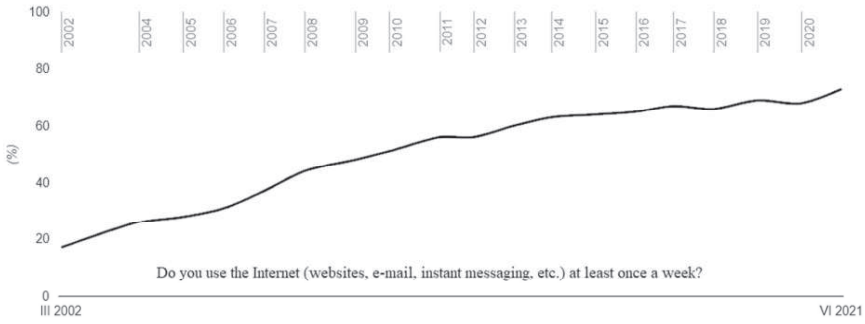
The increasing complexity of the conditions for the functioning of society, especially the speed and complexity of changes in the environment of various organizations, makes it necessary to modify the existing systems (Bytniewski et al., 2013). In this context, the topic of the university's activity in the virtual space of the internet seems to be the most important and up to date. The very rapid development of e-learning technologies allows higher education institutions, in first-, second- and third-degree studies, as well as "lifelong learning" in postgraduate studies and courses that allow for acquiring new skills and give new qualifications, to become easily accessible regardless of the spatial arrangements of stakeholders in the educational process. As the issues related to:

- the level of education of the population,
- lifelong learning (including distance learning systems),
- an innovative, knowledge-based society,
- the information society

are still priorities in European development strategies, but to fit in with these strategies and to meet the challenges of competition, universities need to take action to provide an increasingly better (at least in technological terms) offer.

Considering the CBOS (Centrum Badania Opinii Społecznej – Public Opinion Research Center is an opinion polling institute in Poland, based in Warsaw) reports that, looking back from the beginning of this century, the number of users has been steadily increasing and currently more than two thirds of Poles use the internet (Figure 1). In September 2020, 22.4 million internet users in Poland connected to the web via personal computers and laptops. 24.4 million used mobile devices for this purpose. Access to the internet in Polish households, according to the Central Statistical Office (GUS) data for 2020, was at the level of 90.4%. This includes inhabitants of rural areas and small towns, which are not usually the seats of universities, yet this percentage is also significant (rural areas – 89.3%, towns of up to 100 thousand inhabitants – over 89.7%).

Figure 1
Use of the internet by Poles



Source: www.cbos.pl/PL/trendy/trendy.php?trend_parametr = korzystanie_z_internetu.

Considering the data presented above, expanding the educational offer of universities with the possibility to attend some classes remotely is an exceptionally accurate action and introducing e-learning at universities is the subject of interest of researchers. The case study of the University of Houston-Downtown presented by Kuciapski (2018) focuses on the integration of e-learning with traditional academic didactics and the possibilities of transferring the experience of the American university to Poland. Woźniak-Zapór, Grzyb and Rymarczyk (2015) present the results of research on the implementation of an e-education system at the Andrzej Frycz Modrzewski Krakow University.

Thanks to the appropriate tools, the educational process can be transferred, in whole or in part, from the real space to the virtual space of the internet.

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The prototypes of this kind of education were correspondence courses based on sending materials to the learner in the form of printed materials, audio and video cassettes. Sometimes, these activities were combined with special radio or television programs. E-education is a consequence of the development and application of information technologies to remote education. Tele-learning is the creation of a connection by means of communication technologies between individuals and resources for learning purposes (Collis, 1996). The wide spread of the internet guarantees that a large group of students can be reached without the need to construct a dedicated infrastructure intended only for teaching purposes (Hauke & Owoc, 2003).

According to many researchers examining e-education, its possibilities and advantages include (Bednarek, 2008; Janczyk et al., 2010; Hyla, 2016; Siemieniecki, 2007; Stecyk, 2008):

- no territorial restrictions and high flexibility;
- cost reduction (among other things, elimination of travel costs);
- centralization of the learning process;
- standardization and repeatable quality of training;
- facilitated contact with the tutor;
- convenience of implementation (mode of participation);
- contextualization, multithreading and individualization;
- interactive and engaging format;
- good complementarity with other methods;
- the possibility of making better use of resources;
- sharing graphics, video, audio from locations anywhere in the world;
- a dialogue with virtually every user;
- education for people with disabilities who can learn and study at home without losing access to the same sources of knowledge as their non-disabled counterparts.

Higher education students frequently use social network technology for study purposes and this usage can be best described as knowledge sharing, that is: peer-to-peer sharing of learning materials and resources by uploading, linking and downloading them to designated social network technology based groups that are created, managed and initiated by students themselves. Students share voluntarily and frequently. Sharing and using shared materials has become an integral part of students' study routine. They assess sharing practices positively and believe that it improves their academic achievements (Bouton et al., 2021). Therefore, materials and tools for social network technology (e.g., a learning platform with such a functionality) offered by a university, where academic teachers will also be an element of the community, is one of the steps towards the virtualization of universities.

Virtualization of educational activities materializes through e-learning tools (there are many terms in the literature, depending on the author of

the publication and the approach; in this paper, the terms: tele networking, e-learning, e-education, e-learning will be used interchangeably).

In their pilot project, Rauer et al. (2021) show how students can gain valuable and relatively accessible experience of international cooperation through the participation in cross-university virtual teamwork.

The current legal regulations are an obstacle which, by definition, undermines the idea of modern academic education, reducing it to a form of blended learning (b-learning) and preventing, for the time being, full virtualization in the form of e-learning (Dąbrowski, 2013). But not only legal restrictions are a hindrance to the full virtualization of teaching in higher education; Finlay et al. (2022) indicate serious barriers to the application of such methods, showing that student satisfaction scores may be especially insightful in a student cohort enrolled in an applied sport program.

Universities do not only provide education at the level of bachelor's, master's, or doctor's studies. There are also scientific as well as administrative activities allowing for supervision, control of the effects and efficient teaching and research work.

3.3. E-administration of Universities

The use of e-learning (or, as shown earlier, b-learning) for virtualization of the didactic activity of a university obviously makes it necessary to introduce university e-administration, even if only in the student-deanery, student-lecturer, lecturer-deanery relations. A situation in which a student, having completed the required classes in a remote system, must appear in person at the university only for the lecturer to make an entry in his/her student book and for the student to deliver the student book to the Dean's Office seems far from consistent when it comes to the overall shaping of mutual relations and ways of communication between these entities.

At universities, information systems collect data on students, enrolment in individual lectures and laboratories, as well as students' academic achievements. In addition, information is collected about lecturers, timetables, courses, etc. There must be an efficient administrative and management apparatus over the whole process. Additionally, the interests of students and employees must be reconciled (Łosowski, 2010). Even though they also exist as private universities or universities of religious associations, universities however – just as schools with the privileges of public schools – are part of the state education system. Hence, the virtualization of university administration can also be understood as the construction of e-administration as most generally construed in the literature.

E-government is moving towards knowledge-based systems, in the sense that the internet technology (and related communication) is becoming ubiquitous and the administration will provide services in an intelligent way (Chmielarz, 2007). The services provided by university e-administration can have many various stakeholders; these can be individuals like university

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offices or various external institutions, e.g.: students, academics, libraries, Dean's Office, faculties, departments, ministries, POL-on (the IT system at the Ministry of Education and Science, containing databases of, i.a., scientists, students, diploma theses and documents). The most obvious element of a university e-administration is the virtual Dean›s Office, where a logged-in student can check his/her personal data processed in the system, obtain information about received grades, pay any tuition fees, read about announcements (including changes in a class schedule) and individual decisions made by the university authorities, enroll in specializations, courses, seminars. It also permits the submission of applications in matters related to studies. However, a university e-administration system can offer much more. One of very popular systems is the University Support System for Studies – USOS. It is the result of cooperation between the largest Polish universities. The system was created because of demand for a comprehensive IT tool for managing university studies. The main applications of USOS are as follows:

- enrolment and matriculation,
- electronic student cards,
- the teaching offer (classes, groups, dates, tutors),
- management of the course of study (study programs, enrolment, records of grades),
- student applications,
- theses and diploma examinations (electronic archiving of diploma theses),
- scholarships,
- dormitories,
- payments for educational services,
- student work placements,
- surveys,
- reporting,
- staff matters (full-time and part-time employment, settlement of salaries, etc.),
- careers office,
- university archives.

Owing to its broad scope of applications, USOS plays the role of a central point for collecting information from the entire university, which significantly facilitates the management of studies, enables the unification of university procedures and allows for effective introduction of university-wide initiatives such as a common offer of optional courses for students of all fields of study, language classes, physical education classes, certification exams, as well as central authorization of students and employees on a university's websites, generating unique numbers of student books and diplomas. Storing data in a digital form significantly reduces the number of traditional documents, allowing, among others, for eliminating paper protocols with grades, examination cards, student applications and even student books (www.usos.edu.pl, accessed 2021-06-20).

The implementation of e-government at a university is itself the subject of scientific research. For example, Popiołek (2014) presents the issue of the USOS system adoption by the academic community.

3.4. Virtualization of Research

Virtualization of scientific activities of a university should be understood as transferring research activities to the internet space as well as online search for literature and data and online publication of papers. There are many tools in the virtual space of the internet to assist researchers, four of which are listed below with the specifics of the site.

ResearchGate (https://www.researchgate.net/) – a free, international, researcher-focused social network where it is possible to:
– make publications available,
– connect and collaborate with colleagues, co-authors, and specialists,
– get access to statistics and information on who has read and cited published works,
– jointly and remotely connect and resolve research problems.

Mendeley (https://www.mendeley.com/) – a free academic community building a tool allowing for:
- making the results of research publicly available,
- contact with other researchers;
- tracking the use of published works;
- search for publications by other authors;
- management of found materials;
- compilation of citation lists and bibliographies.

The portal of the National Information Processing Institute (OPI) (nauka-polska.pl) contains, among others, a search engine for Polish scientists and researchers.

Scopus (https://www.scopus.com/freelookup/form/author.uri), in its open part, is a search engine for profiles of scientists and researchers.

As our (yet unpublished) research has shown, universities in Poland differ in the degree of virtualization of activities in the three areas mentioned. At the same time, their authorities realize that virtualization is now a necessity. It turned out that there is a need for a tool that will help universities to assess the degree of their virtualization and, at the same time, indicate the path to the next levels of virtualization of research, education, and administration. These findings underpinned the development of our proposed VIM model.

By dividing universities' activities into these three basic areas mentioned earlier, we can consider separately their levels of virtualization. After such a partial study, the results can be aggregated to determine the overall stage of virtual maturity. It will be possible to place universities in the created framework of virtual maturity. Our framework allows for determining the advancement of virtualization as a process encompassing the whole university in all fields of activity.

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4. Related Works

The topic of virtualization maturity models has already been attracting researchers' attention for several years. However, to the best of our knowledge, the very area of higher education institutions' virtualization models has not yet been deeply investigated. The research has rather focused on more technical and business issues. For example, at the beginnings of the internet, Baumann et al. (1999) proposed the "Network Maturity Model for Internet Development". Subsequently, maturity models were elaborated, e.g., for:

- organizational infrastructure virtualization (Staten et al., 2009);
- SaaS applications virtualization (Lin et al., 2011);
- Green IT through virtualization (Bose&Luo, 2011; Rajani MCA & Phil, 2012; Buchalcevova, 2015);
- C2C social business model (Sukrat & Papasratorn, 2018);
- Enterprise agility through virtualization (Osinga, 2019);
- Virtualization of physical IT assets (Nishant et al., 2020).

The virtualization maturity of universities is hardly covered. Secundo et al. (2016) developed a maturity model to measure the efficiency of academic technology transfer offices. Their model covers several areas including industry links and networking. The research and didactics areas have not been covered. Recently, Sherstobitova et al. (2021) have addressed the issue of smart university capacity evaluation. A smart university is understood, inter alia, as the one where educational teams collaborate remotely with teams from other universities. Hence, networking maturity is taken into consideration in the area of didactics. Virtualization maturity is not covered.

The framework proposed in our paper is the broadest and the most complete one. It encompasses every area of a university's activities: the educational, research, and administrative ones. Hence, it allows for a complete and profound assessment of a university's virtualization maturity.

5. The Idea of Maturity Models

The notion of maturity can be defined as "the state of being complete, perfect or ready" (Lahrmann et al., 2010). Kania (2013) points out that maturity develops gradually because of a process during which the desired features are shaped, enabling the performance of certain tasks. Hence, maturity is a state that can be graded from extreme immaturity to extreme maturity. However, to be able to determine the extent to which the phenomenon being assessed is mature, it must be possible to measure the maturity. This need was the beginning of the so-called maturity models.

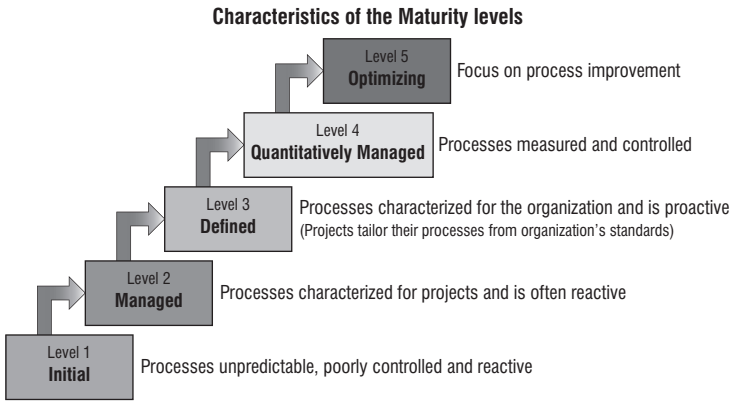
From a formal point of view, the maturity model is a means of identifying the strengths and weaknesses of a certain field in an organization, consisting of several levels of maturity of the field used to evaluate the organization (or a part of it) and to map its development paths (Lahrmann et al., 2010).

It can also be said that "maturity models are used to describe, explain and assess the life cycle of growth (...) and consist of a model and a questionnaire used to assess the level of maturity" (Hribar Rajterič, 2010) or "maturity models may be understood as artefacts which serve to solve the problems of determining a company's status quo of its capabilities and deriving measures for improvement" (Becker et al., 2009).

Most often, maturity models are derived from the widely recognized and appreciated CMM (Capability Maturity Model), developed in 1991 for the software development process. On its basis, in 2001, an integrated model CMMI (Capability Maturity Model Integrated) was created, focused on the assessment of process maturity (Kania, 2013). In this model – as in all subsequent models from different domains – the research domain is assessed at one of the five (most common) levels of maturity. A description of these basic levels, using the process approach as an example, is presented in Figure 2.

The main purpose of using maturity models is to codify knowledge about what good processes or actions should look like, how to evaluate them (criteria) and how to improve them (Kania, 2013), as well as to obtain systematic guidelines and a clear way of assessing the implemented solutions (Mircea, 2012).

Figure 2
Description of individual maturity levels on the example of the process approach (CMM model)



Source: Godfrey, 2011.

Maturity models can be broadly divided into (Kania, 2013):
- descriptive – allowing to determine the level of maturity of an organization,
- prescriptive – describing the target state and allowing to determine how far an organization is from it,
- transition models – defining what steps an organization must take to move from the current state to the desired one.

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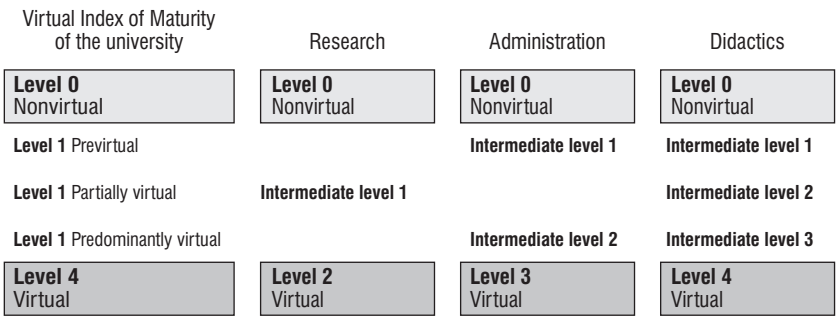
As said, maturity models were initially created for process management and software development, but due to their usefulness and relatively high flexibility, which make them easy to modify, they were quickly adopted in other areas of application e.g., Business Intelligence, big data and many others. Also, in the case of university virtualization efforts, maturity models can be a useful tool for assessing the implemented solutions.

6. Virtualization Maturity Framework

During the building of a virtual index of maturity (VIM) model for a university, it was assumed that the VIM will have (like most known maturity models) five levels. However, an analysis of three identified and distinguished spheres of university activity (didactics, administration and research) that make up the VIM showed that it was impossible (or very difficult) to distinguish so many levels in each of these spheres. Therefore, the number of levels in individual spheres is different and corresponds to the number of differentiating factors. The VIM was constructed in such a way that, under no circumstances, could the VIM value be unequivocally determined based on the level in only one of the spheres. The same value of the level of a given sphere may correspond to different values of VIM depending on the configuration of the values in the other two spheres, as illustrated in Figures 4–7. Only the knowledge of the levels in all spheres allows to calculate the VIM. The maximum level of VIM is a special case, as it is achieved only when the values of all the components of the levels in considered spheres reach their maximum levels. The formula for calculating VIM is given below and numbered (1).

The extreme levels for the VIM index and for considered individual spheres are called: Nonvirtual and Virtual. The intermediate levels are named only for the VIM and for individual spheres they are only numerically marked, as illustrated in Figure 3.

Figure 3
List of the main and component levels



Source: Own elaboration.

The method used for model construction is very flexible and can be used more widely if necessary. Appropriate, minor modifications of the constants included in the formula allow to change the number of given spheres that make up the overall index and the number of intermediate levels in individual spheres, while maintaining the final effect in the form of an overall index ranging from 0 to 4.

6.1. The Virtual Maturity Model of Universities

3 – number of examined (taken into consideration) areas, i.e., **didactics, administration, research**

x1 – level of virtuality achieved in the area of ***didactics***
(expressed by integers from ***0*** to ***4***) where:

0 – **Nonvirtual** level
- *Classes are held on campus only, i.e., in classrooms, laboratories, etc.*
- *The dominant form of contact between students and lecturers is direct contact, i.e., physical contact or by means of paper correspondence – e.g., leaving assignments at the department, in the Dean's Office or in special correspondence boxes (compartments); lecturers leave materials to be copied at the university's copy centers. Making course materials available online is an individual initiative of very few academic teachers*
- *The university does not provide online syllabuses for courses within bachelor's and master's degree programs*

1 – First intermediate level
- *Classes are held on campus only, i.e., in classrooms, laboratories, etc.*
- *All mid-semester and final examinations, level tests and competency tests take place at the university only, under supervised self-directed conditions*
- *Student-teacher contact, apart from the face-to-face, i.e., physical contact, is possible online*
- *Some student materials are posted online for download (e.g., on websites, by e-mail, or through a special platform)*

2 – Second intermediate level
- *The university has a distance learning platform with an online examination system, but all the tests and final examinations take place at the university*
- *The courses take place mainly on campus, but there are also blended learning modes available*
- *Own material prepared by the university is posted for download on the internet*
- *Online consultations and group works are organized*

3 – Third intermediate level
- *The university has a remote learning platform with an online examination system and some final exams, assessment and level tests are done remotely*

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- *The courses of bachelor's, master's and doctor's programs are delivered in different modes: on-campus, blended learning or e-learning*
- *Postgraduate courses, all of which or part of which take place remotely, are organized*

4 – **Virtual** level (maximum)
- The university offers first, second or third degree courses (bachelor's/engineering, master's, doctor's) that are entirely delivered online
- Any course can be taken remotely by a student
- Staff and students have email boxes on the university domain

x2 – level of virtuality achieved in the area of ***administration*** (expressed by integers from ***0*** to ***3***) where:

0 – **Nonvirtual** level
- *The university does not have a website or has it in a non-developed, static version*
- *The university does not use any social media*
- *Employees and students do not have email inboxes on the university domain*
- *The university does not use systemic university IT solutions (individual computers, not connected to the university network, work in organizational units of the university)*
- *Only a paper-based workflow is in operation*
- *Recruitment based on documents submitted by the candidates*
- *You can sign up for classes with the teachers or at the Dean's Office*

1 – First intermediate level
- *The university has an extensive, dynamic website*
- *Students do not have email boxes in the university domain*
- *Individual departments, divisions or other units of the university have separate systems with data taken from paper documents and entered by the administrative staff*
- *Recruitment based on documents submitted by the candidates*
- *You can sign up for classes at the teachers' office or at the Dean's Office, but you can also contact the teachers via e-mail*

2 – Second intermediate level
- *The university has an extensive, dynamic website from which various documents can be downloaded*
- *The university is active on social media*
- *Coursebooks are paper-based but there is no documentation of a paper-based semester credit card*
- *Recruitment based on a computerized application system accessible via the internet*
- *Registration for classes via the university's IT system*

3 – **Virtual** level (maximum)
- *There is a university-wide integrated information system (USOS type)*

- *Students and employees can contact the university units by logging into the system dealing with all the matters remotely*
- *Circulation of documents is electronic (including no paper handbooks or coursework)*

x3 – level of virtuality achieved in the ***research*** area (expressed by integers between ***0*** and ***2***) where:

0 – Virtual
- *The university library provides access **to paper version of materials only***
- *Scientific publications with the university's affiliation are published **in hard copy only***
- *Conferences organized by the university **are held on campus only***

1 – Intermediate level
- *The university library provides mainly paper version of borrowed materials, but there is also a chance to use various subscribed specialist databases, access electronic version of journals, etc.*
- *The university's scientific publications (including the university's scientific journals) are published in similar proportions in both paper and electronic versions*
- *Part of the university library's collection is digitized (including books originally published in hard copy) and there is a chance to use it **remotely**, along with various subscribed specialist databases, electronic version of journals etc.*

2 – Virtual
- *All the university library's collections are digitized and it is possible to use them **remotely**, along with various subscribed specialist databases, electronic version of journals etc.*
- *All research papers with university affiliation are available to staff and students **remotely***
- *All academic publications can be accessed **remotely***
- All academic conferences organized by the university are online, or if they are held on campus, then remote participation is always an alternative

VIM – Virtual Index of Maturity of the university (expressed as an integer from ***0*** to ***4***)

$$VIM = \left[\left(\sum_{i=1}^{3}\left((x_i + 1) * \frac{5}{{}^{\max}x_i + 1}\right)\right) div\ 3\right] - 1 \qquad (1)$$

where:
x_i – The number of component levels in the spheres under consideration,
${}^{\max}x_i$ – The number of maximum component levels in the spheres under consideration.

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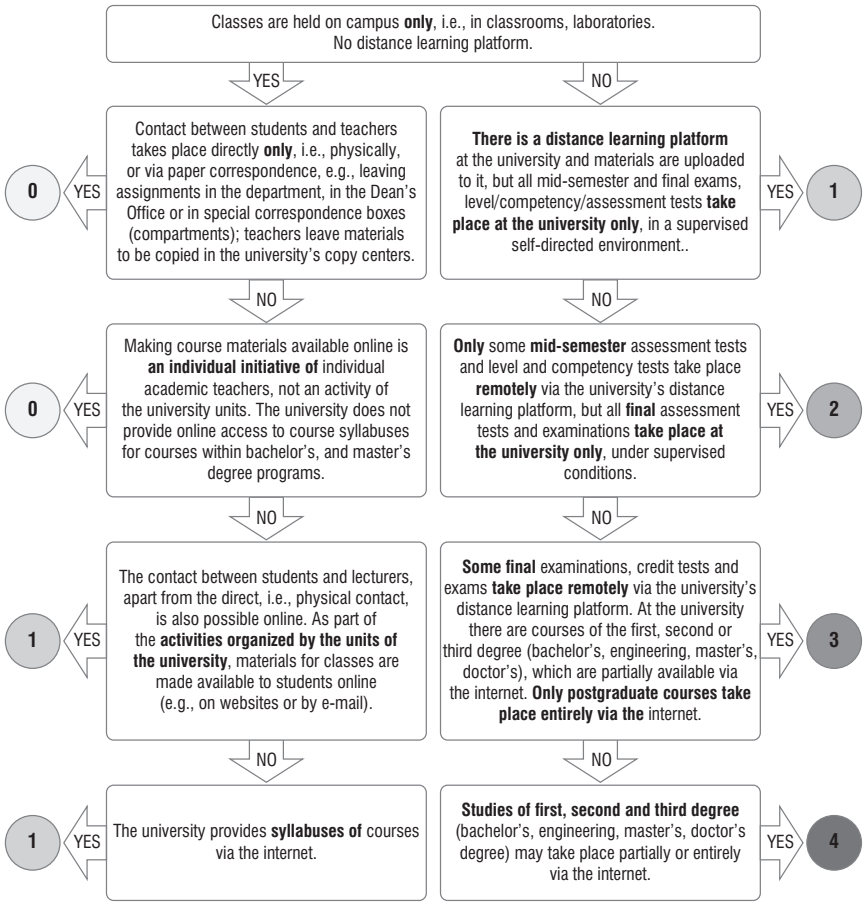
Figure 4
Possible configurations of the component levels in relation to increasing VIM values

Source: Own elaboration.

6.2. Classification Scheme Card for the State of Virtualization of Universities in the Sphere of Didactics

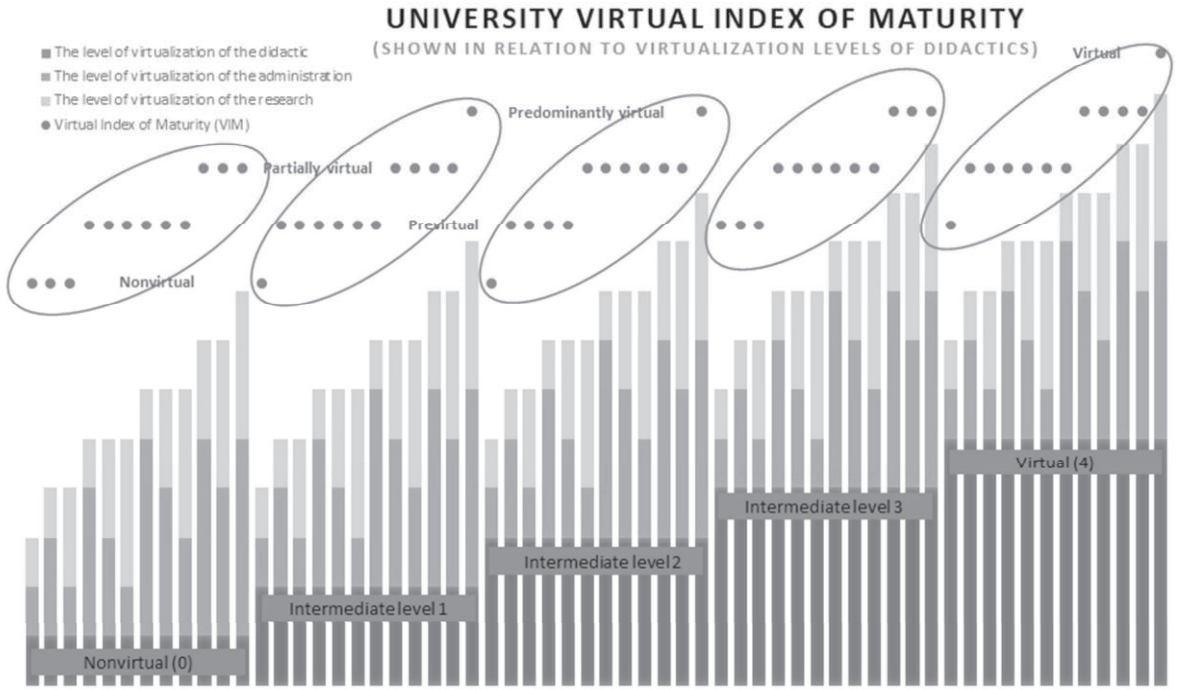
Figure 5
Classification scheme in the sphere of didactics



Source: Own elaboration.

https://doi.org/10.7172/1644-9584.96.4

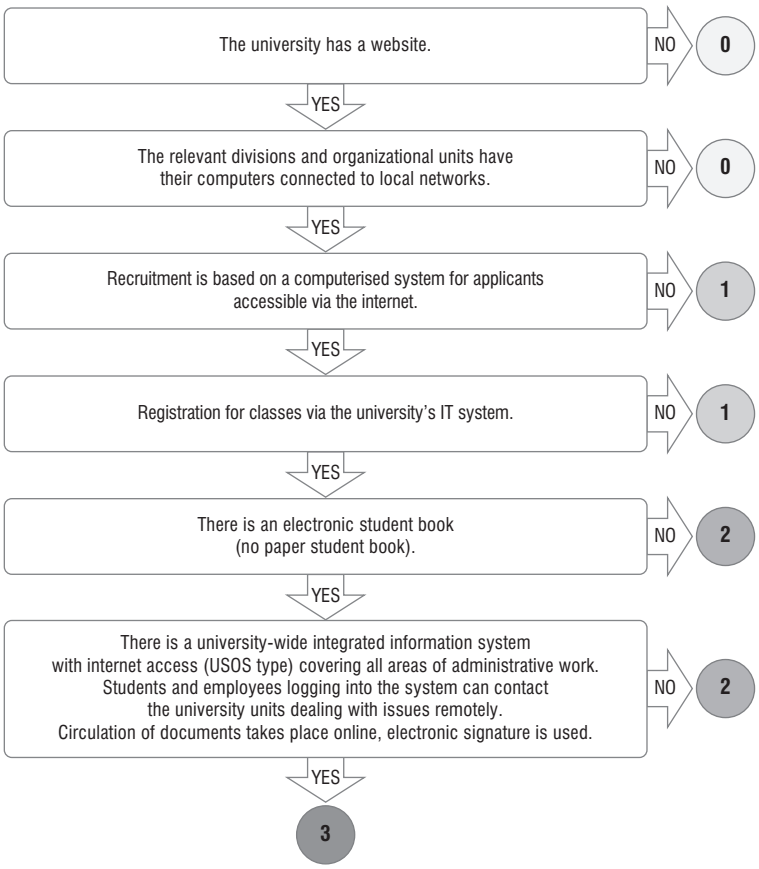
Figure 6
Possible VIM levels in relation to increasing values of the didactics sphere level. Configurations of other component levels



Source: Own elaboration.

6.3. Classification Scheme Card for the State of Virtualization of Universities in the Sphere of Administration

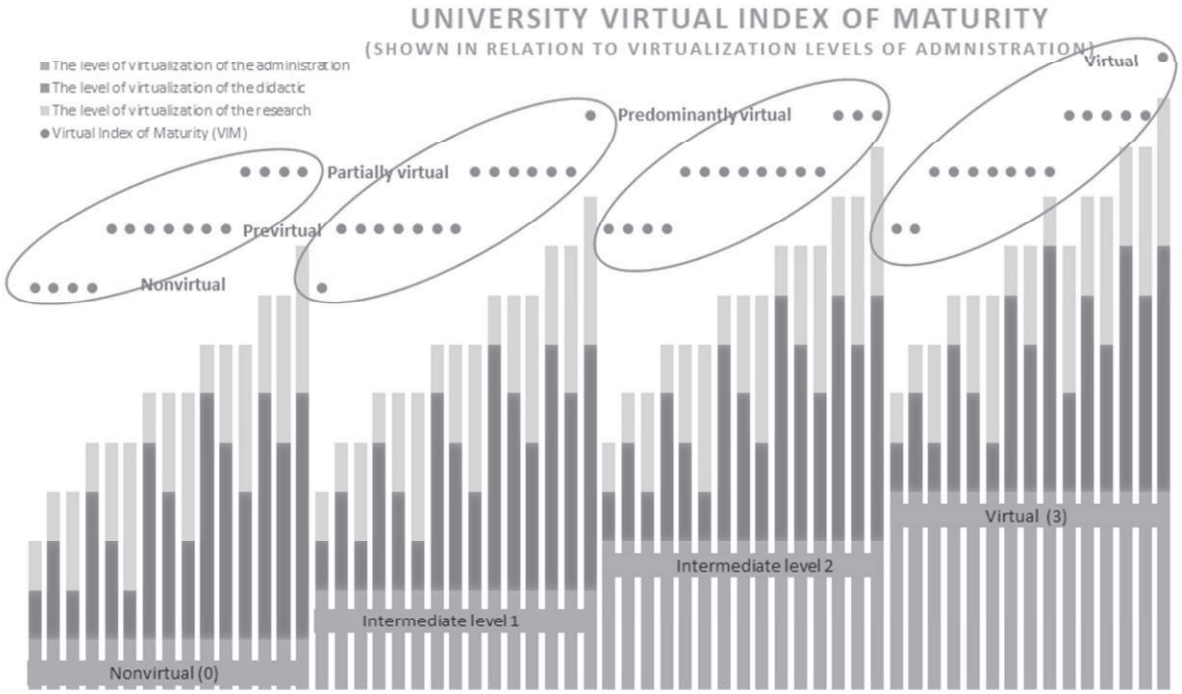
Figure 7
Classification scheme in the sphere of administration



Source: Own elaboration.

https://doi.org/10.7172/1644-9584.96.4

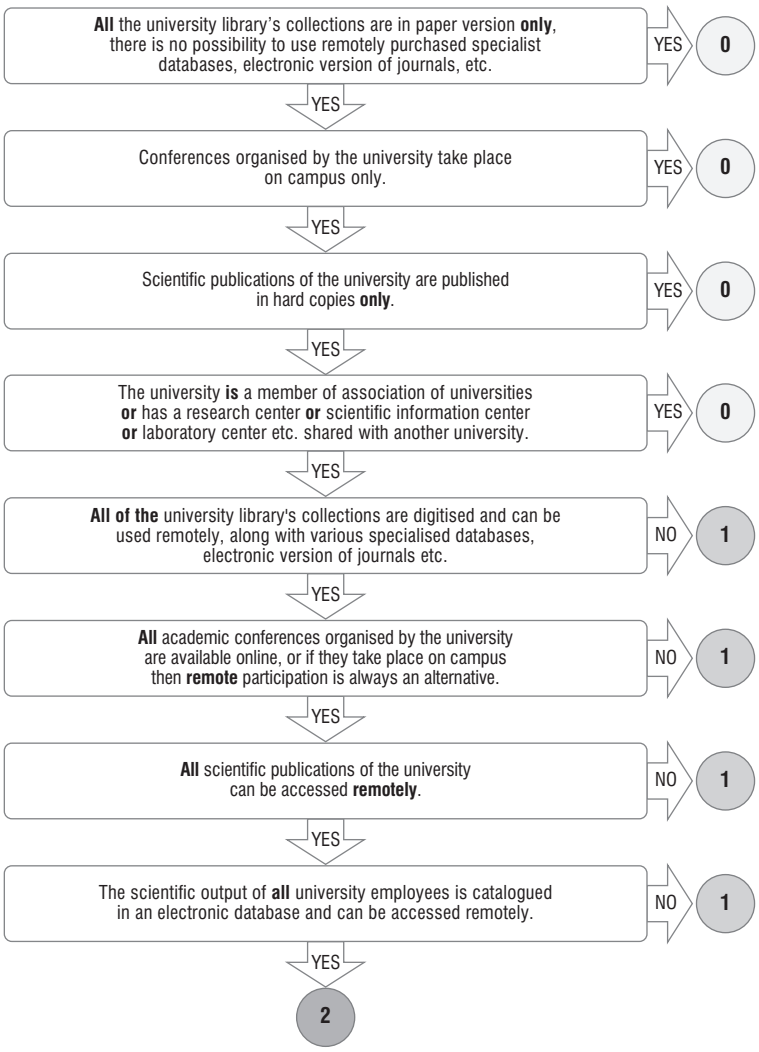
Figure 8
Possible VIM levels in relation to increasing values of the administration sphere level. Configurations of other component levels



Source: Own elaboration.

6.4. Classification Scheme Card for the State of Virtualization of Universities in the Sphere of Research

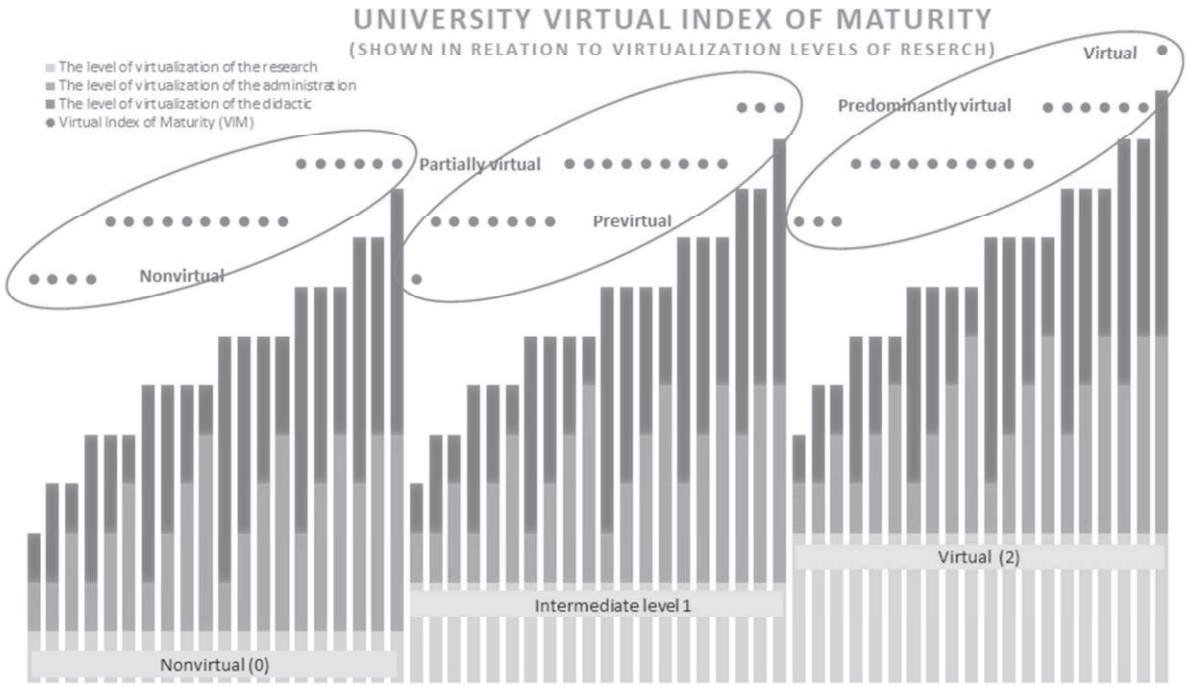
Figure 9
Classification scheme in the sphere of research.



Source: Own elaboration.

https://doi.org/10.7172/1644-9584.96.4

Figure 10
Possible VIM levels in relation to increasing values of the research sphere level. Configurations of other component levels



Source: Own elaboration.

The model proposed in this section is a comprehensive solution. With the help of cards containing classification schemes, it allows to determine the values of virtualization levels for individual identified spheres of university activity, thanks to which, in turn, it is possible to calculate VIM. If there is a need to modify the model during the empirical applications, it is possible, as mentioned before, in a simple way because the model is flexible and scalable.

7. Conclusions

The framework proposed in our paper is the broadest and the most complete maturity assessment tool for universities willing to operate online effectively and to form alliances. It allows to assess each area of operations: the didactic, research and administrative one. Having proposed this tool, our paper makes both theoretical and practical contributions to this field of research.

Theoretical Contributions

The need of web presence and of cooperating via networks has already been recognized by educational institutions, including universities. However, research on virtualization maturity issues has not yet touched the area of higher education – as we presented in the "Related works" section. Moreover, the existing maturity models aimed at measuring virtualization maturity may be considered somehow incomplete, because they focus on each of the spheres of university activity separately. Most of the work is done on didactics virtualization. Our framework brings all of the spheres together in one coherent model dedicated to all university operations. Hence, the framework of VIM (Virtual Index of Maturity) extends previous studies on virtualization maturity by combining these three important spheres of universities activity and embedding them in a context of higher education.

Practical Implications

This paper offers guidance for university authorities willing to respond to the challenges of virtualization that the modern world poses to universities. This study shows how to measure maturity in this dimension to elaborate the future path of development. A university that successfully implements virtualization will have far better results and achievements in today's globalized education and research environment. In practice, the model draws attention to the need for a holistic perception of university activities in the context of virtualization. VIM can be used for three purposes:

- a diagnostic tool to determine the current state of virtualization (descriptive function),

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- as a set of guidelines for determining the path to achieve specific successive states of virtualization (prescriptive function),
- as a benchmarking tool (comparative function).

The use of VIM in practice may facilitate the cooperation of universities – the ones with the same virtualization level will be able to collaborate within the field of virtualization projects and activities more easily. In turn, cooperation with a university with a relatively higher VIM index may allow for the implementation of good practices and the adoption of detailed solutions that will increase the level of virtualization. In the case of acquisitions, transformations and mergers of the universities, such an objective determination of the level of virtualization may facilitate the preparation of activities allowing for the unification (maintaining the highest level of virtualization in a group). VIM can also be part of the valuation for business activities. Summing up, the presented new framework can be comprehensively used by university practitioners in their efforts to respond to current challenges.

Limitations and Future Research

Although our paper provides important contributions to both theory and practice in the area of universities' virtualization operations, we are aware of some of its limitations.

One of the limitations of the model, especially in the case of external university research, is the possible difficulty in collecting all the necessary information needed to classify and determine the level of virtualization. Since transparency and openness are elements of virtuality, in order to overcome this limitation it can be assumed that the lack of access to information reduces the VIM value.

The proposed framework needs validation and testing. This should lead to the development of best practice and contingency guidelines for university managers, researchers and other stakeholders concerned with virtualization issues. By understanding the idea of VIM, universities should be able to benefit significantly from their virtual presence.

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